River Turtles and One Dam Lake: Two Imperiled *Graptemys* Species in the Pearl River and Potential Impacts of the Proposed One Lake Project

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ABSTRACT. – **The impacts of human modifications of rivers and associated riverine fauna is well documented, especially following the construction of impoundments. In the Pearl River system of Mississippi and Louisiana, two endemic *Graptemys* species are found (*G. oculifera*; *G. pearlensis*), but little is known of their densities in urban stretches near Jackson even though both are species of conservation concern. I completed replicate basking surveys of five equidistant stretches of the Pearl River and at nearby oxbow lakes for both *Graptemys* species during the summers of 2017 and 2018 using spotting scopes and binoculars. I documented both species in all river stretches, and basking densities for both species were generally higher in stretches upstream and downstream of Jackson compared to middle stretches. *G. oculifera* were found in greater densities than *G. pearlensis* in all stretches (14 – 69× higher). *Graptemys oculifera* was found in four of the six oxbow lakes surveyed, but mean densities decreased 10× compared to river stretches; *G. pearlensis* was absent from all oxbow lakes. Densities for a generalist turtle species, *Trachemys scripta*, increased 35× in oxbow versus river habitats. The middle three survey stretches (~15.9 river km) are inclusive of a proposed river impoundment project – the One Lake Project – for flood control and economic development. Estimates of direct and indirect impacts of this project are sizeable for *G. oculifera* (direct impact: 1690; indirect: 2138) while estimates for *G. pearlensis* are lower (direct: 87; indirect: 110). This project will surely**

alter existing riverine processes and will favor generalist turtles like *T. scripta* that prefer non-flowing, lake settings at the expense of riverine *Graptemys* species. The One Lake Project will be a major setback to both *Graptemys* species in and around the project area, and it will negatively impact the recovery potential of both species.

Key Words. – basking density surveys; channelization; chelonians; *Graptemys oculifera*; *Graptemys pulchra*; imperiled; Jackson, Mississippi; Ross Barnett Reservoir; river turtle; urban river

The Southeastern United States is considered one of the most diverse turtle faunas worldwide, harboring over 10% of the world's turtle species (Buhlmann et al. 2009), but over 60 percent of southeastern U.S. turtle species are considered imperiled and at risk for declines (Buhlmann and Gibbons 1997). Along with direct threats to turtles such as collection for the pet trade, threats to riverine habitat are also widespread, and these threats include channelization, de-snagging (i.e., removal of trees and deadwood from the river channel), pollution, excess sedimentation, and impoundments (Moll and Moll 2004). For the latter, reservoirs alter riverine hydrology (for review, see Bunn and Arthington, 2002) and are a leading contributor to species endangerment in the United States, particularly in the southeastern United States (Czech et al. 2000).

One such river system with historical modifications is the Pearl River system of central Mississippi and southeastern Louisiana. The Pearl River is a biologically diverse river drainage, but multiple modifications around Jackson, Mississippi were made before and following the historic Easter Flood of 1979 (i.e., the flood of record for the region). In the 1960s the Pearl River was channelized to improve floodwater conveyance through a historically sinuous segment of the river and leveed to reduce flooding in the city of Jackson. In 1963, the river system was further altered by the construction of the Ross Barnett Reservoir upstream of Jackson, and this reservoir regulates downstream flows via a dam and spillway system. Last, along with these modifications, this entire stretch of the Pearl River has also been historically subjected to degraded water quality via industrial, municipal, and residential sources (McCoy and Vogt 1979). Degraded water quality persists into the present due to copious amounts of litter (WS, pers. obs.) and untreated sewage that has been discharged into the Pearl River and tributaries in the Jackson area (Mississippi Department of Environmental Quality, https://www.mdeq.ms.gov/mdeq-issues-water-contact-advisory-for-pearl-river-and-other-streams-in-the-jackson-area/; accessed 28 May 2019).

Since the Easter Flood of 1979, several flood control lake options have been proposed for flood protection of Jackson (e.g., Shoccoe Dry Dam, Two Lakes Plan, Lefleur Lakes Plan), and most of these have also touted recreational and waterfront development potential. Currently, another proposed flood control plan, the One Lake Project, is slated to impound ~16 river km of the Pearl River while also widening and deepening portions of the river channel. However, this would alter riverine processes and subsequently, these altered processed impact the associated aquatic fauna, including riverine turtles, that are dependent upon natural river flows (Graf 2006).

Two endemic riverine turtle species occur sympatrically in the Pearl River system of central Mississippi: *G. oculifera* (ringed sawback; Baur 1890) and *G. pearlensis* (Pearl map turtle; Ennen et al. 2010). Even though information has been collected for both species throughout the river system (e.g., Shively 1999; Jones and Hartfield 1995; Selman and Jones 2017), there is relatively little population data for either species throughout the stretch of the Pearl River that flows through downtown Jackson including the section slated for the One Lake Project. Therefore, the objective of this study was to determine the abundance of each species via basking density surveys in this urbanized stretch of the Pearl River, while also determining densities in local oxbow lakes in the Jackson area (Hinds/Rankin counties) for comparison. Additionally, three of the Pearl River stretches I surveyed are inclusive of the proposed One Lake Project, and these data may also serve as pre-construction data for post-construction comparisons if the project is completed.

METHODS

River Study Sites. — The Pearl River is a moderately sized Gulf Coastal Plain river (22,348 km^2) that drains much of central Mississippi and southeastern Louisiana. Mississippi's capital city of Jackson is located near the midpoint of the drainage in central Mississippi and also downstream of the Ross Barnett Reservoir. Five equidistant and consecutive river segments (5.3 rkm each; total 26.5 rkm) of the Pearl River were selected for river turtle surveys in Jackson (Hinds and Rankin counties; Fig. 1). Two of these stretches (S1, S2) occur upstream of a lowhead dam on the Pearl River that pools water for municipal water intake. Three survey stretches occur downstream of the lowhead dam (S3-S5). Stretch 1 and 5 are similar because they are more natural and have alternating sandbar and cutbank sections with high levels of submergent and emergent deadwood. They also have an intact riparian forest buffer (i.e., forest up to the river's edge), and the primary trees species include Water Oak (*Quercus nigra*), Bald Cypress (*Taxodium distichum*), Overcup Oak (*Quercus lyrata*), and Black Willow (*Salix nigra*). Stretch 2 is a relatively straight portion of the Pearl River with fewer sandbar and cutbank sections, but similar to S1 and S5, S2 maintains moderate-high amounts of deadwood and a mostly intact riparian forest buffer. In the S2 reach, a large, 4 lane state highway crosses the Pearl River. Stretch 3 and 4 encompass the channelized stretch of the Pearl River, with additional human modifications including mowing, herbicidal application of vegetation, and desnagging of riverine deadwood. The river lacks a riparian forest buffer along most of S3 and S4, and instead, it is bordered by a grassy/shrubby margin. In-stream differences include few deadwood snags and a shallow, sandy bottom with few deep sections. Within S3 and S4, two major interstate highways, one U.S. highway, a local road, and two railroad bridges cross the Pearl River. Of the five stretches surveys, three occur within the planned zone of the One Lake Project (S2-4), while two stretches occur upstream (S1) and downstream (S5) of the proposed One Lake Project.

Oxbow Lake Study Sites. — In 2018, I also surveyed six local oxbow lakes of the Pearl River located in Hinds and Rankin counties. Four different oxbow lakes at Lefleur's Bluff State Park, collectively known as Maye's Lakes, were surveyed from seven different observation sites (Fig. 2). The four lakes included Wing Lake (1 site; 3.0 hectares; 0.35 km surveyed), Cypress Lake (1 site; 2.8 hectares; 0.36 km surveyed), East Maye's Lake (3 sites; 8.7 hectares; 1.02 km combined), and West Maye's Lake (2 site; 6 hectares; 1.07 km combined). All of these sites contain wetland vegetation characteristic of floodplain oxbow ponds including baldcypress, swamp tupelo (*Nyssa aquatica*), red maple (*Acer rubrum*), and the invasive Chinese tallow tree (*Triadica sebifera*). The primary difference was that Wing Lake was shallower than the other three lakes, and it had considerable pond surface coverage of white water lily (*Nymphaea odorata*).

A fifth oxbow lake, YMCA Lake (1 site; 1.6 hectares; 0.43 km), was surveyed, and it is located ~3 km south-southwest of the Maye's Lakes. This oxbow lake is a historic channel of the Pearl River, but it was isolated from the river following channelization and levee construction in the 1960s. The YMCA Lake is surrounded by commercial development, and trees line ~50% of the shoreline and are primarily silver maple (*Acer saccharinum*), American sycamore (*Platanus occidentalis*), and Chinese tallow tree.

The sixth oxbow lake I surveyed was Crystal Lake (4 sites; 0.95 km combined), and it is ~1.5 km south-southeast of the YMCA Lake. It is considerably larger than the other oxbow lakes at ~55 hectares. Similar to the YMCA Lake, Crystal Lake is a historical channel of the Pearl River that was cut off following channelization, and it is the largest segment of the historic Pearl River that was isolated following levee construction. The margins of the lake are primarily water oak, black willow, red maple, and Chinese tallow tree. The lake is eutrophic with considerable amounts of duckweed (*Lemna* sp.), alligatorweed (*Alternanthera philoxeroides*), and water hyacinth (*Eichhornia crassipes*). The margins of the lake are lined with dense stands of cattails (*Typha* sp.) and giant cutgrass (*Zizaniopsis miliacea*). Based on historical imagery, large portions of this lake have transitioned from open water to freshwater and/or floating marsh over the last 20 years.

Methods for Field Observations. — All river survey stretches were floated by boat during the months of June and July 2017 and 2018. I completed 6 replicate surveys for S1 and 5 replicate surveys for S2-5 (total of ~137.8 rkm surveyed). For the latter, flooding during June 2017 prevented us completing a sixth round a surveys for S2-5. When sandbars were present, the boat was moored on the upstream end of the sandbar, and I identified and counted basking turtles via spotting scope while walking down the sandbar (similar to Selman and Qualls 2009). I identified the sex and life history class (adult/juvenile) of *Graptemys oculifera* and *G. pearlensis* when possible based on descriptions by Jones and Selman (2009) and Lovich et al. (2009), respectively. In the absence of sandbars, visual surveys consisted of floating downstream (< 5 km/hr) in an outboard motorboat with two observers that were equipped with binoculars. Each observer counted opposite banks of the river and another person served as data recorder. I also used a Nikon Coolpix p900 digital camera with 83× optical zoom to take photographs of large basking aggregations of turtles that were difficult to identify from a distance with binoculars. All surveys were completed between the mid-morning to mid-afternoon hours (~0900–1530 hrs) when environmental conditions were conducive for basking. I avoided surveying on days when large amounts of rain or thunderstorms occurred in order to minimize the variance of conditions during our observations and for safety reasons, respectively.

For the lake study sites, I completed four replicate spotting scope surveys for basking turtles during June and July 2018. Surveys were made from fixed locations along the bank of the oxbow lakes using a spotting scope with tripod. Survey distances along both the river and banks were estimated using the measuring tool in GoogleEarth Pro (v. 7.1.5.1557; Google Inc., Mountain View, California, USA).

Data Analysis. — I used a one-factor ANOVA to determine if *G. oculifera* densities were equal across the five stretches surveyed. If differences were observed, I used a Tukey-Kramer post hoc analysis to determine differences among stretches. Because *G. oculifera* juvenile densities were non-normally distributed, I used a nonparametric Wilcoxon Rank Sums test to determine if the number of *G. oculifera* juveniles was equal among the stretches surveyed, and then used a nonparametric pairwise comparison to determine differences among stretches. *Graptemys pearlensis* densities were non-normally distributed, so I used a nonparametric Wilcoxon Rank Sums test to determine if *G. pearlensis* densities were equal among the sites; a nonparametric pairwise comparison to determine differences among stretches. Because lake and river densities were non-normally distributed, I used two Wilcoxon Rank Sums tests to determine to determine if lake and river densities of both *G. oculifera* and *Trachemys scripta* (Red-eared Slider) were equal.

Because the One Lake Project will impact S2-S4, it seemed essential to estimate the number of turtles that would be impacted by this project in those stretches. During basking density surveys I detect only a fraction of the overall population because many individuals remain underwater. Thus, it is important to consider the basking frequency (i.e., the percent of the population that may be basking at any one time) in order to estimate total population size. There is currently no basking frequency data for either *G. oculifera* or *G. pearlensis*, but monthly basking frequency information is available for two ecologically equivalent species from the Pascagoula River, *G. flavimaculata* (Selman and Qualls 2011) and *G. gibbonsi* (Selman and Lindeman 2015), respectively. Based on the study by Selman and Qualls (2011) and the time of year, I estimated that only 20 – 30% of the *G. oculifera* population was observed during June/July basking surveys. Similarly, I estimated that only 10 – 15% of the *G. pearlensis* population was observed during June/July basking surveys based on the study by Selman and Lindeman (2015). These percentages were used as correction factors to calculate estimated population sizes within the One Lake Project area for both species by multiplying the high and low correction factor by 1) the minimum count I observed for each stretch, 2) the mean of all counts for that stretch, and 3) the maximum count I observed for each stretch (e.g., six calculations; three different counts and two percentage correction factors). I made calculations for stretches directly impacted (S2-S4) and also for stretches that might be indirectly impacted (S1, S5). Indirect impacts may include siltation/contaminants flowing downstream and/or the movement of turtles from the impacted area into neighboring stream reaches that may alter the population dynamics (i.e., crowding). The mean and range of these six estimates will be reported.

RESULTS

Summary of Pearl River Surveys. — In all river surveys during 2017 and 2018, I observed 5,643 turtles in 137.8 total rkm surveyed. I observed eight species basking during these surveys including (in order of rank abundance): *Graptemy oculifera* (4,843 individuals; 85.8%), *Graptemys pearlensis* (188; 3.3%), *Pseudemys concinna* (134; 1.0/rkm; 2.4%), *Trachemys scripta* (64; 0.46/rkm; 1.1%), *Sternotherus carinatus* (49; 0.36/rkm; <1%), *Graptemys pseudogeographica* (31; 0.22/rkm; <1%), *Apalone mutica* (9; 0.07/rkm; <1%), and *Apalone spinifera* (3; 0.02/rkm; <1%). The remaining turtles were either unidentified *Graptemy*s sp. (80; 1.4%), unidentified *Apalone* sp. (43; <1%), unidentified Emydids (129; 2.2%), and unknown turtle species (70; 1.2%).

Status of Graptemys oculifera. — The mean number of *G. oculifera* observed per survey for all stretches surveyed was 186 turtles (113 ♂, 52 ♀, 15 Juveniles, 6 Unknown Sex), and densities for all stretches averaging 35.0 per rkm. Adults of both sexes and juveniles were observed within all stretches surveyed. However, there was considerable variability in densities among the stretches (Table 1). *Graptemys oculifera* densities were statistically different among the five river stretches ($F_{4,26}$ = 11.3, $p < 0.0001$; Fig. 3). Results from the Tukey-Kramer post hoc analysis indicated that S1 (52.5/rkm) and S5 (45.2/rkm) had higher densities than S3 (11.7/rkm) and S4 (20.6/rkm), but S1 and S5 densities were not higher than those observed in S2 (41.5/rkm); S2 had higher densities than S3, but it did not have higher densities S4; there was no difference in S3 or S4 densities (Table 1). *Graptemys oculifera* were observed in higher densities than *G. pearlensis* during all surveys at all sites (Fig. 3). For all surveys combined, *G.*

oculifera was observed at 25× higher densities in comparison to *G. pearlensis*, while within site comparisons of both species ranged from a low of 14× higher in S5 to a high of 69× higher in S2.

Graptemys oculifera juveniles were found in all stretches surveyed indicating that females nest successfully in all stretches. However, juvenile basking densities were different among the stretches surveyed ($\chi^2 = 17.1$, df = 4, $p = 0.002$; Table 1). For comparisons, S2 had higher juvenile counts (mean: 36.8 per survey) than S3-5 (S3 – 2.6, S4 – 5.8, S5 – 6.0), and S1 (23.5) had higher counts than S3-5; there was no difference between S1 and S2 (Table 1).

Status of Graptemys pearlensis. — The mean number of *G. pearlensis* observed for all stretches surveyed was 7.2 turtles (4.1 ♂, 1.9 ♀, 0.7 Juveniles, 0.5 Unknown Sex) per survey with densities of all stretches averaging 1.4/rkm. Adults of both sexes were observed in all stretches, but juveniles were not observed in S3 during any 2017/2018 survey. Contrary to *G. oculifera*, *Graptemys pearlensis* densities were low in all river stretches surveyed (range: 0.4 – 3.2/rkm; Table 2). However, densities were statistically different across sites ($\chi^2 = 20.3$, df = 4, $p = 0.004$; Fig. 3); S5 had higher densities than S1-S4, and S1 had greater densities than S2-4. Too few juveniles of *G. pearlensis* were observed to make comparisons among stretches, but I observed small numbers of *G. pearlensis* juveniles in all stretches except S3 (Table 2).

Oxbow Lake Turtle Community and Densities. — During oxbow lake surveys, I observed 226 turtles in 16.7 km of shoreline surveyed at the six lakes. I observed seven species basking during these surveys including (in order of rank abundance): *Trachemys scripta* (80; 4.8/km; 35.4%), *Pseudemys concinna* (72; 4.4/rkm; 31.9%), *Graptemys oculifera* (48; 2.9/km; 21.2%), *Graptemys pseudogeographica* (3; 0.18/km; 1.3%), *Apalone spinifera* (3; 0.18/km; 1.3%), *Sternotherus carinatus* (2; 0.12/km; <1%), and *Chrysemys dorsalis* (1; 0.06/km; <1%; Table 3).

The remaining individuals were unidentified Emydids (14; 6%) and unknown turtles (3; 1.3%). *Graptemys pearlensis* was absent from all lake locations.

Graptemys oculifera was observed in 4 of 6 oxbow lakes surveyed including E. Maye's, W. Maye's, Cypress, and Crystal lakes; they were absent from Wing Lake and YMCA Lake (Table 3). *Graptemys oculifera* densities combined in all lake locations averaged 3.4/km, and this was 10x less in all river stretches surveyed (35.0/rkm for all river stretches). Further, *G. oculifera* populations were strongly male-biased in lakes (38 M, 7 F, 1 unknown sex). A single *G. oculifera* juvenile was observed twice at only a single location, and it seems likely that it was the same individual (location 2, East Maye's Lake). When considered collectively, *G. oculifera* densities in lake sites were significantly lower than those observed at river sites ($\chi^2 = 44.5$, df = 1, $p < 0.0001$; Fig. 3).

Trachemys scripta was a relatively minor component of the river turtle basking community (0.46/rkm; 1.1%), but it was the most dominant species observed in lake settings (4.8/km, 35.4%). For *T. scripta*, basking densities increased 10× in lake settings, and their relative abundance increased 32×. When considered collectively, *T. scripta* densities in lakes were significantly higher than those observed at river sites ($\chi^2 = 10.2$, df = 1, $p = 0.001$; Fig. 4).

Estimated Population Impacts of the One Lake Project. — Using a 20 – 30% visual correction factor for undetected *G. oculifera* individuals, the mean number of turtles impacted in S2-S4 using the six calculations would be 1690 individuals (range: 917 – 2745; Table 4). This is inclusive of males, females, and juveniles that appear to represent a viable and reproducing population along all stretches. For *G. oculifera* individuals that might be indirectly impacted by the One Lake Project and using the similar correction factor approach, the mean number of *G.*

oculifera impacted upstream in S1 would be 1169 individuals (range: 865 – 1945) and 969 individuals in S5 (range: 830 – 1455; Table 4).

Using a 10 – 15% correction factor for undetected *G. pearlensis* individuals, the mean number of turtles impacted would be 87 individuals (range: 20 – 170; Table 5). Using the similar correction factor approach to account for indirectly impacted individuals, the mean number of turtles impacted upstream in S1 would be 35 individuals (range: 20 – 55) and 75 individuals in S5 (range: 40 – 125; Table 5).

DISCUSSION

Status of Graptemys oculifera. — Much research has been conducted on *G. oculifera* since the species was listed as federally threatened in 1986 (USFWS 1986) and after the *G. oculifera* recovery plan suggested studies to be undertaken (Stewart 1988). While data existed for S1 (aka, Lakeland site in Jones and Hartfield 1994; Jones 2017), no data on *G. oculifera* densities was available for the S2-5 in the immediate vicinity of Jackson. My observations indicate that *G. oculifera* persists throughout this highly modified section of the Pearl River and sometimes occur in relatively high densities. This is surprising, encouraging, and indicative of the recovery potential of the species. Even in the most degraded habitat of S3 and S4, *G. oculifera* still exhibited recruitment; I observed nesting *G. oculifera* females and juveniles within these river stretches, while numerous turtle nesting crawls and depredated nests were also observed on sandbars. Because most of the riparian vegetation has been removed via in S3 and S4, it seems likely that nesting females are not limited to only nesting on sandbars; a high elevation patch of sandy substrate in the grassy/shrubby margins would likely suffice for many turtles. Thus, even though the river is channelized and sandbars are not as plentiful in these stretches, it seems likely that females could use this alterative nesting habitat.

Within the channelized portion (S3, S4), there are few deadwood basking structures for turtles compared to upstream (S1, S2) and downstream sections (S5). Along with fewer deadwood basking structures, the river channel has also filled substantially with sand/sediment, and this has left some river sections with a shallow river bottom and few deep refuges preferred by *Graptemys* species. Nonetheless, both *Graptemys* species persist in this setting, albeit at lower densities. Within S3/S4, there were short river sections where moderate to high amounts of deadwood and an intact riparian zone could be found. In these stretches, densities of *G. oculifera* were very concentrated even though few individuals might be observed upstream and downstream of these locations.

It is not surprising that densities in the most natural sites (S1 upstream and S5 downstream) were highest given the higher prevalence of sandbars, cutbanks, intact riparian buffer, and copious amounts of riverine deadwood for basking. The upstream section (S1) has been the focus of long-term study by R.L. Jones (site name Lakeland), and this population of *G. oculifera* is one of the most stable populations surveyed since the 1980s (Selman and Jones 2017; Jones 2017). Mean densities of *G. oculifera* in S1, S2, and S5 exceeded the densities observed by prior researchers throughout much of the Pearl River system with the exception of two study sites: Ratliff Ferry and Columbia (Selman and Jones 2017). However, in the altered stretch of the Pearl River (S3 and S4) mean densities of *G. oculifera* are 2-3× less than the other river stretches surveyed, but these densities are not small and insignificant. Densities in S3 and S4 are similar to densities observed by Shively (1999) in the Bogue Chitto River (4 – 17/rkm), and they exceed or are similar to densities in the lower Pearl River (0 – 15.7/rkm, Dickerson and Reine 1996; 20.4/rkm, Lindeman 1998).

Jones (2017) found that *G. oculifera* at the Lakeland site (S1 in this study) have been increasing significantly since 2000; four other study populations were in decline during that same time period. Based on our observations of high juvenile counts in S1 and S2, it seems that recruitment in this section is exceptionally high with juveniles composing 10-20% of basking *G. oculifera* individuals. This is likely a major contributor to the recent increase in population size, but the reasoning behind this high recruitment is puzzling. Considering the location of the site within an urban/suburban landscape, one would assume that recruitment would be low because of increased contaminants entering from urban streams and nest mortality associated with subsidized predators (e.g., raccoons). Indeed, for the latter I noticed numerous depredated nests on sandbars throughout all river stretches. However, an alternative explanation for the higher recruitment is that S2 mostly lacks discrete sandbars, and therefore, females may select nest sites that are atypical (e.g., small sand banks along the river) rather than larger sandbars that predators can easily target. With nests being more diffuse along these stretches and not concentrated on sandbars, predators may not be as successful in raiding nests and nest success may be higher. This would have to be explored further in future studies.

G. oculifera in the oxbow lakes of Lefleur's Bluff State Park are able to seasonally reconnect with the main river population during flood events; the river achieved flood stage ~5 times between June 2017 and July 2018. For a similar species, Jones (1996) observed radio-marked *G. flavimaculata* (Yellow-blotched Sawback) that seasonally moved into and out of oxbow lakes in the lower Pascagoula River. However, my observations of few juveniles indicates that oxbow lake populations of *G. oculifera* exhibit nominal recruitment, and may be ecological "sinks" that are dependent upon individuals emigrating from the river. Therefore, I suspect that many of the individuals observed in Crystal Lake, a lake separated from the river by levees, are likely older adults that are merely "hanging on" in suboptimal, eutrophic habitats. Because they are disconnected from the Pearl River, emigration out of the system or immigration into the system is likely minimal. Thus, *G. oculifera* at the Crystal Lake site likely does not appear to represent a viable population in the long-term.

Status of Graptemys pearlensis. — *G. pearlensis* was recently petitioned by the Center for Biological Diversity to be considered a candidate for federal protection status (vis-à-vis *G. gibbonsi*; U.S. Fish and Wildlife Service 2011). Most surveys to date throughout the Pearl River system indicate that the species occurs in lower abundance relative to *G. oculifera* (Dickerson and Reine 1996; Lindeman 1998; Selman and Jones 2017). Similarly, my study found that *Graptemys pearlensis* densities were significantly lower during all surveys and in all stretches in comparison to *G. oculifera*. Our observed densities fall within most previously reported basking densities for *G. pearlensis* (range: 0 – 7 per rkm), with only a few sites having densities exceeding our observations (range: 10 – 15/rkm; Pearl River at Columbia, Selman and Jones 2017; portions of the Bogue Chitto River, Shively 1999). Based on *G. pearlensis* capture data from Selman and Jones (2017) for the Lakeland population (i.e., S1, north of Lakeland Drive), this population has undergone a significant population decline since the 1980s. For example, in the 1980s and 1990s, 20 to 40 individuals were regularly captured per trapping effort, while by 2013, only a single individual was captured with similar effort (Selman and Jones 2017). It is unknown why the population has declined in this stretch, but water quality and riverine regulation at the reservoir may have impacted prey item presence and availability (Selman and Jones 2017). Ultimately, the chances of localized extinctions are higher in small populations like *G. pearlensis* due to environmental and demographic stochastic events.

I did not find *G. pearlensis* in any of the oxbow lakes surveyed. Similarly, Lindeman (1998) did not find them in Maye's Lakes in the mid-1990s. Thus, even though these oxbow lakes may seasonally flood and be connected to the river (with the exception of isolated Crystal and YMCA Lakes), *G. pearlensis* appear to strictly use riverine habitat. This is suggestive of a narrower habitat niche than *G. oculifera*.

Estimated Population Impacts of the One Lake Project. — The One Lake Project currently proposes to impound ~16 rkm of the Pearl River, and that river stretch encompasses S2 – S4. Clearly, the One Lake Project has the potential to impact populations of both *G. oculifera* and *G. pearlensis* along with other riverine turtle species and other aquatic species of conservation concern in the Pearl River (e.g., Gulf Sturgeon, *Acipenser oxyrinchus desotoi*). If the One Lake Project is implemented to deepen and widen the river, it will dramatically alter the hydrologic regime of this stretch of the Pearl River. It will convert the habitat from a lotic, river setting to a more lentic, lake setting (Bunn and Arthington 2002). With changes to the riverine processes, the habitat of this lake will be vastly different than the existing riverine habitat. For example, one of the major changes that is likely to occur is lower water velocities, and this will also limit bank erosion and the additional inputs of deadwood snags along the banks. Lower river velocities will also not impede the growth of dense stands of emergent vegetation similar to the habitat I observed at Crystal Lake. Lower water velocities also minimize the annual scouring of sandbars, and without this, woody vegetation will encroach on nesting sandbars likely in the form of Chinese tallow trees. I would suggest that such a change to the Pearl River would be considered "habitat alteration", a primary threat to *G. oculifera* as outlined in the U.S. Fish and Wildlife Ringed Sawback Recovery Plan (U.S. Fish and Wildlife Service 1986).

As a result of the altered habitat, I predict that the One Lake Project would benefit generalist turtle species that thrive in these settings at the expense of specialist riverine turtle species. Indeed, this is exactly what I observed in the oxbow lake surveys: *G. oculifera* densities declined tenfold compared to in river settings, *G. pearlensis* were absent, and *T. scripta* densities increased tenfold. Further, *G. oculifera* recruitment appeared to decline dramatically in oxbow lake settings. Therefore, generalist turtles that are better adapted to the non-flowing water will replace riverine specialist like *G. oculifera* and *G. pearlensis* over time. Following construction, I suspect that turtles will still occur in the One Lake project area, but rare species like the Ringed Sawback and Pearl Map Turtle will disappear over time, and the area will be colonized by cosmopolitan species.

In order to test this potential scenario (i.e., lake generalists will replace riverine specialists), the data contained herein provide baseline basking densities for comparison if the One Lake Project is constructed. If the One Lake Project comes to fruition, monitoring of the *G. oculifera* and *G. pearlensis* populations within these stretches is paramount. A major effort should be made to capture and mark individuals in this population for future monitoring to determine the extent of impacts to these populations. Furthermore, habitat and flow data should be collected to determine the changes to their riverine habitat. Lastly, individuals should be tracked throughout the process to determine if animals move upstream, downstream, or stay within the project area.

In summary, the impacts of the One Lake Project to this population will be major in intensity and long-term in duration. Our survey data indicates that *G. oculifera* can occur in great abundance throughout the One Lake Project area and recruitment/reproduction are better in this stretch than what has been observed in other *G. oculifera* populations. Thus, if completed, the One Lake Project will be a major setback to both *Graptemys* species and negatively impact their recovery potential.

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Table 1. Mean basking densities of *Graptemys oculifera* within the Pearl River near Jackson, Mississippi. Below each mean is a parentheses that includes: (the minimum – maximum count for that stretch; standard deviation). For Mean *G. oculifera*/rkm comparisons, different superscript letters are indicative of significantly different densities among river stretches. *G.o.* = *G. oculifera*, rkm = river km.

Stretch	Mean *G.o.* Male	Mean *G.o.* Female	Mean *G.o.* Juvenile	Mean *G.o.* Total	Mean *G.o.*/rkm
1	163.7	83.8	23.5	279.5	52.5 ^{a}
	(82-242; 66)	(53-112; 27)	(7-40; 13)	(173-389; 98)	(18)
2	130.6	45.6	36.8	220.6	41.5 ^{ab}
	(97-166; 30)	(32-56; 12)	(11-60; 20)	(149-295; 63)	(12)
3	30.2	28.2	2.6	62.6	11.7 ^{c}
	(22-44; 3)	(12-50; 14)	(0-4; 1.7)	(42-77; 15)	(2.8)
4	69	29.8	5.8	109.6	20.6 ^{b,c}
	(31-113; 34)	(19-43; 11)	(1-17; 6)	(59-177; 49)	(9.1)
5	161.2	66.2	6.0	240.4	45.2 ^{a}
	(121-223; 39)	(34-106; 31)	(2-12; 4)	(166-291; 47)	(8.8)
Total	**113.0 (66)**	**52.0 (59.6)**	**15.3 (17.0)**	**186.3 (102)**	**35.0 (19.2)**

Table 2. Mean basking densities of *Graptemys pearlensis* within the Pearl River near Jackson, Mississippi. Below each mean is a parentheses that includes: (the minimum – maximum count for that stretch; standard deviation). For *G. pearlensis*/km density comparisons, different superscript letters are indicative of significantly different densities among river stretches. *G.p.* = *G. pearlensis*, rkm = river km.

Stretch	**Mean *G.p.* Male**	**Mean *G.p.* Female**	**Mean *G.p.* Juvenile**	**Mean *G.p.* Total**	**Mean *G.p.*/rkm**
1	4.8	1.0	1.8	8.2	1.5 [b]
	(2-9; 2.6)	(0-2; 0.89)	(0-3; 1.2)	(6-11; 1.7)	(0.4)
2	1.6	0.8	0.4	3.0	0.6 [b,c]
	(0-4; 1.5)	(0-2; 1.1)	(0-1; 0.5)	(2-4; 0.4)	(0.2)
3	0.8	1.0	0	2.0	0.4 [c]
	(0-2; 0.8)	(0-3; 1.2)		(0-5; 2.0)	(0.38)
4	2.6	2.4	0.4	5.8	1.1 [b,c]
	(0-5; 1.8)	(1-4; 1.3)	(0-1; 0.5)	(1-8; 2.9)	(0.5)
5	10.6	4.6	0.6	17.0	3.2 [a]
	(7-19; 4.8)	(2-11; 3.8)	(0-1; 0.5)	(12-25; 6.1)	(1.1)
Total	**4.1 (4.3)**	**1.9 (2.3)**	**0.7 (0.9)**	**7.2 (6.1)**	**1.4 (1.1)**

Table 3. Diversity and abundance summary of basking turtle observations in six oxbow lakes within the Pearl River floodplain in Hinds and Rankin counties, Mississippi. *A.s*. = *Apalone spinifera*, *C.d.* = *Chrysemys dorsalis*, *G.o.* = *Graptemys oculifera*, *G.p.* = *Graptemys pearlensis*, *G.ps*. = *Graptemys pseudogeographica*, *P.c.* = *Pseudemys concinna*, *S.c.* = *Sternotherus carinatus*, *T.s.* = *Trachemys scripta,* and X = absent.

Lake	**Length Surveyed (km)**	**# Species**	***A.s***	***C.d.***	***G.o.***	***G.p.***	***G.ps.***	***P.c.***	***S.c.***	***T.s.***	**Emydid?**	**Turtle?**
Crystal	3.8	3	X	X	11	X	X	8	X	12	0	0
Cypress	1.4	4	X	X	9	X	1	40	X	3	0	0
E. Maye’s	4.1	5	X	X	24	X	2	12	1	15	4	1
W. Maye’s	4.3	5	X	1	4	X	X	4	1	32	8	1
Wing	1.4	2	X	X	X	X	X	3	X	8	0	0
YMCA	1.7	3	3	X	X	X	X	5	X	10	1	0

Table 4. Visual correction factor calculations (20 – 30%) for *G. oculifera* within, upstream, and downstream of the One Lake Project area. Stretch 2-4 are inclusive of the One Lake Project area, and S1 and S5 are upstream and downstream of the project area, respectively. Min = minimum count observed on that stretch, Mean = the mean of all counts for that stretch, Max = maximum count on that stretch.

Stretch	**Min Count**	**Mean Count**	**Max Count**	**Min x 20%**	**Min x 30%**	**Mean x 20%**	**Mean x 30%**	**Max x 20%**	**Max x 30%**
2	174	220.6	295	870	580	1103	735	1475	983
3	42	62.6	77	210	140	313	209	385	257
4	59	109.6	177	295	197	548	365	885	590
Estimated in Project Area				**1375**	**917**	**1964**	**1309**	**2745**	**1830**
1	173	279.5	389	865	577	1398	932	1945	1297
5	166	240.4	291	830	553	1202	801	1455	970
Estimated Up and Downstream				**1695**	**1130**	**2600**	**1733**	**3400**	**2267**

Table 5. Visual correction factor calculations (10 – 15%) for *G. pearlensis* within, upstream, and downstream of the One Lake project area. Stretch 2-4 are inclusive of the One Lake Project Area, and S1 and S5 are upstream and downstream of the project area, respectively. Min = minimum count observed on that stretch, Mean = the mean of all counts for that stretch, Max = maximum count on that stretch.

Stretch	Min Count	Mean Count	Max Count	Min x 10%	Min x 15%	Mean x 10%	Mean x 15%	Max x 10%	Max x 15%
2	2	3	4	20	13	30	20	40	27
3	1	2	5	10	3	20	13	50	33
4	1	5.8	8	10	3	58	39	80	53
Estimated in Project Area				**40**	**20**	**108**	**72**	**170**	**113**
1	6	8.1	11	30	20	41	27	55	37
5	12	25	17	60	40	125	83	85	57
Estimated Up and Downstream				**90**	**60**	**166**	**110**	**140**	**64**

Figure 1. River turtle survey segments along the Pearl River and oxbow lakes surveyed near Jackson, Mississippi (Hinds and Rankin counties). Numbered markers note the beginning of each of the 5.3 river km stretches that were surveyed. General locations for oxbow lakes surveyed are also depicted here; Lefleur’s Lakes details depicted in Figure 2.

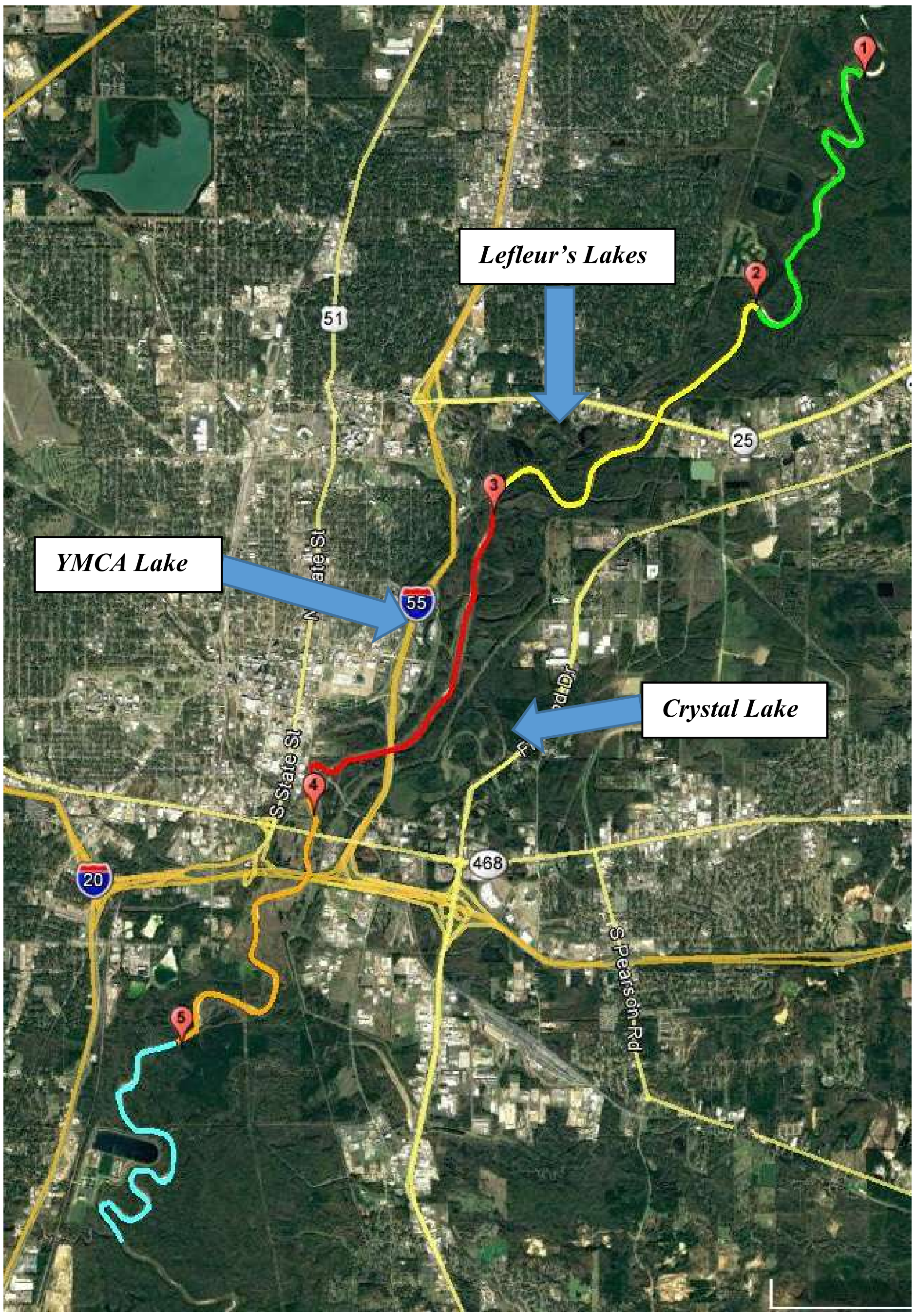

Figure 2. Lake survey sites 1 through 7 at Lefleur's Bluff State Park (Hinds Co.). Survey sites were located at East Maye's Lake (Sites 1-3), Wing Lake (Site 4), Cypress Lake (Site 5), and West Maye's Lake (Sites 6, 7).

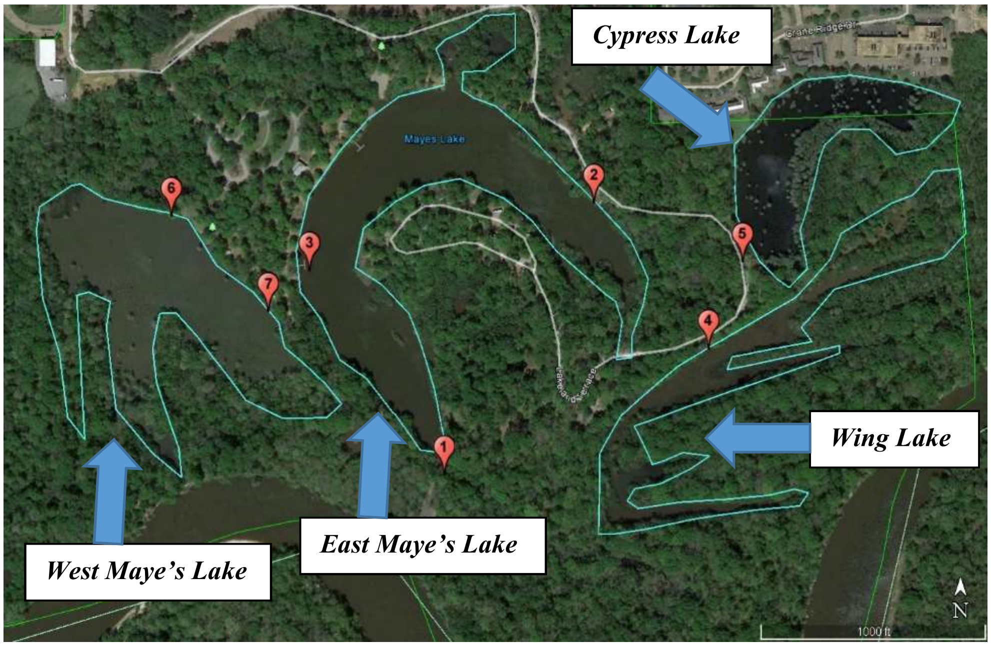

Figure 3. Variability in *Graptemys oculifera* (left) and *Graptemys pearlensis* (right) densities among five survey stretches of the Pearl River. Note the difference in scale on the y axis for each species, and error bars represent one standard error.

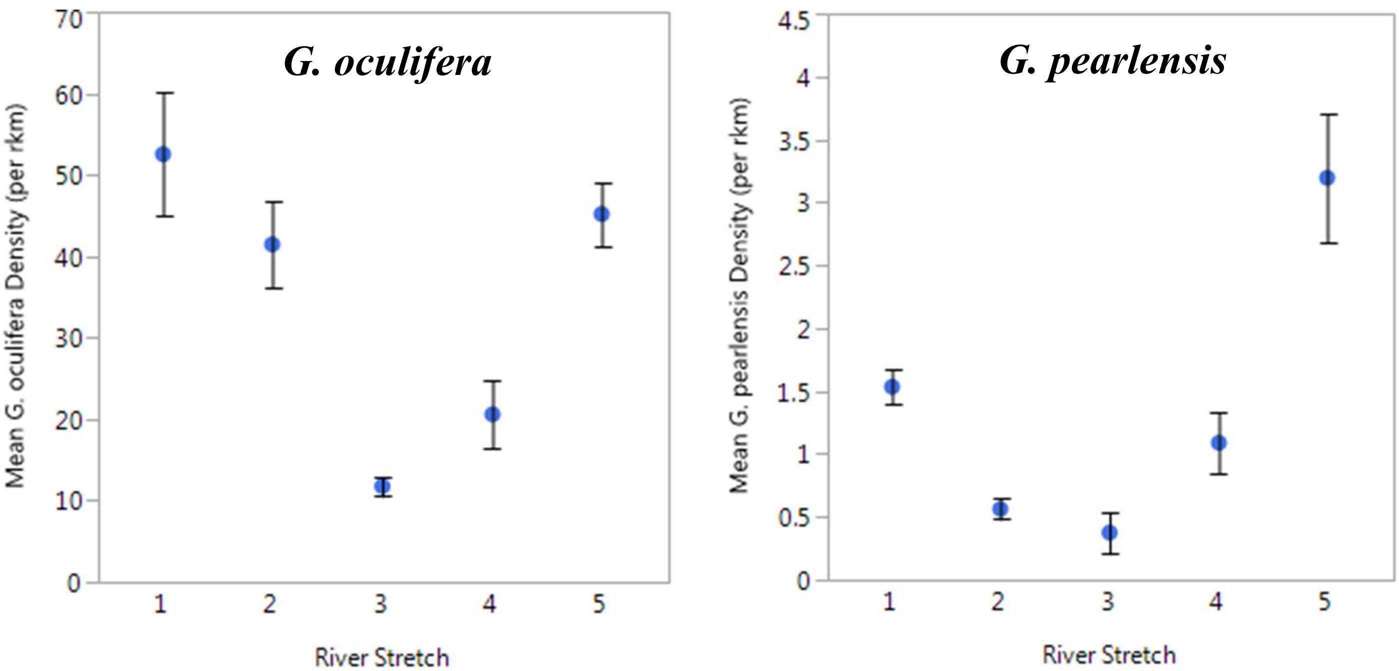

Figure 4. Comparisons of *Graptemys oculifera* (left) and *Trachemys scripta* (right) densities in river versus lake settings. Error bars represent one standard error.